

June 23, 1942.

A. ALFORD

2,287,220

TRANSMITTING ANTENNA

Filed April 9, 1941

4 Sheets-Sheet 1

FIG. 1.

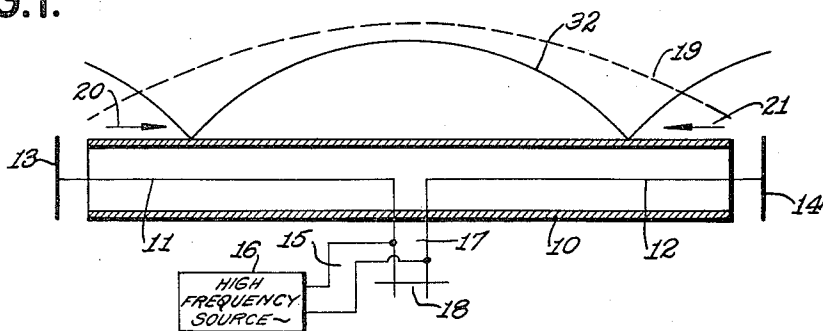


FIG. 2.

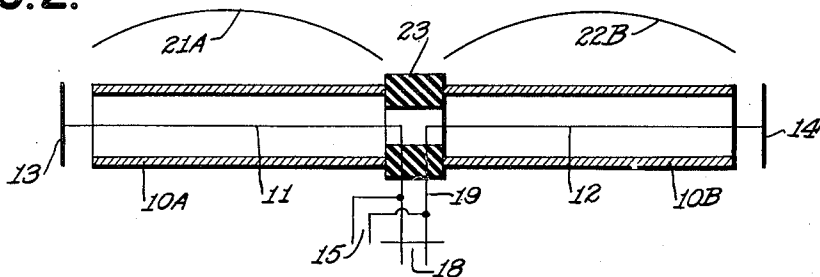


FIG. 3.

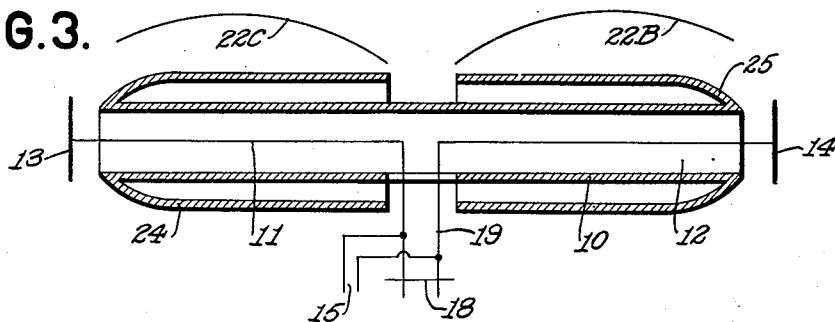
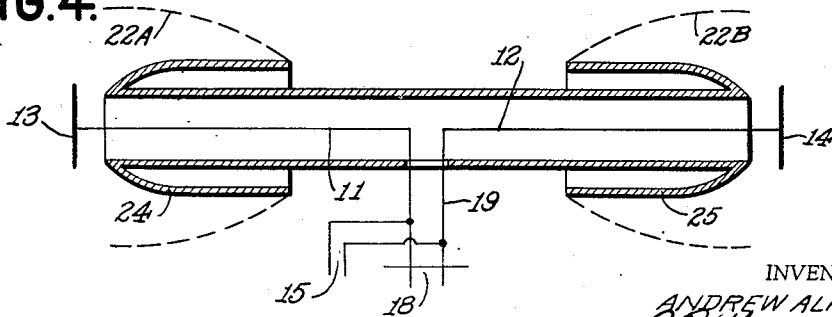


FIG. 4.



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4 Sheets-Sheet 2

FIG. 5.

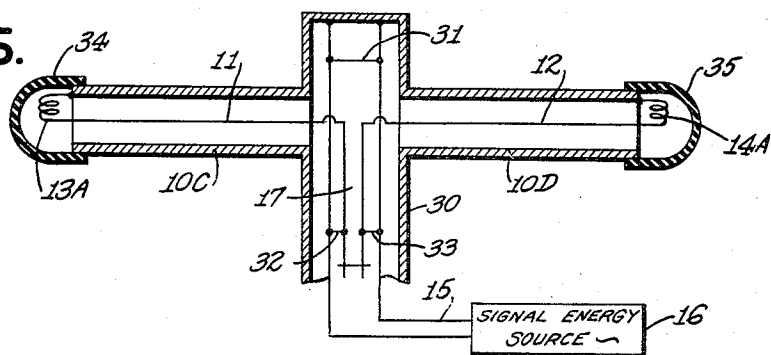


FIG. 6.

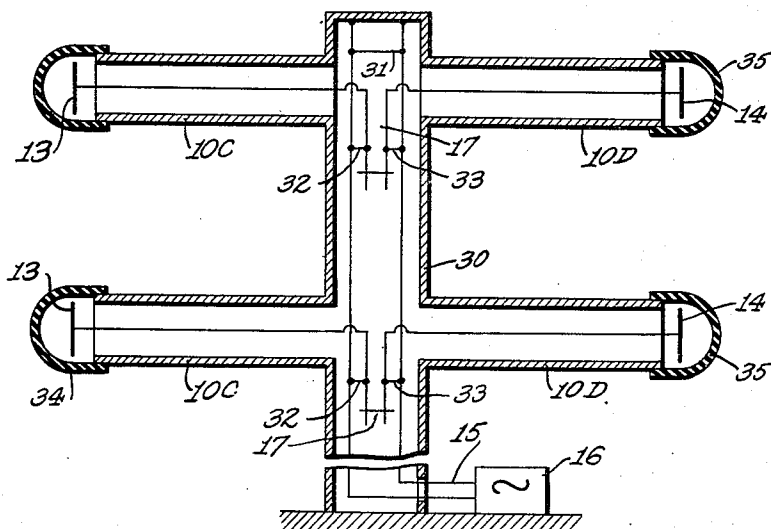


FIG. 7.

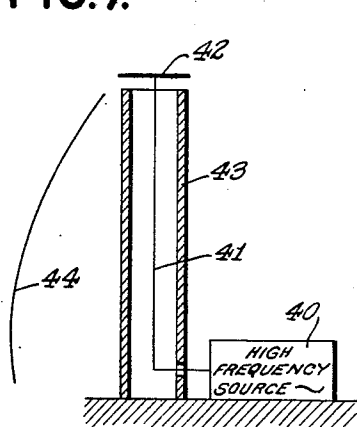
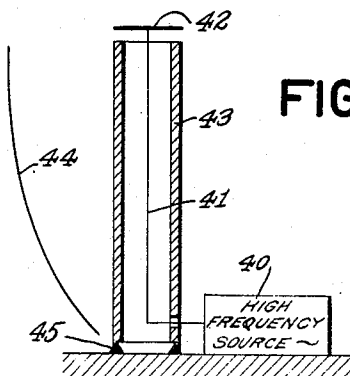


FIG. 8.



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2,287,220

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4 Sheets-Sheet 3

FIG. 9.

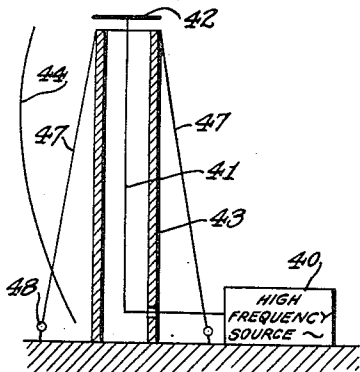


FIG. 10.

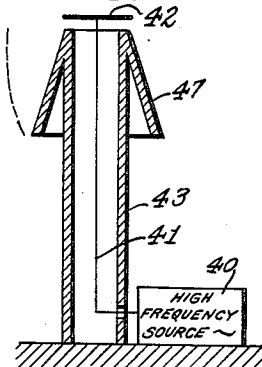


FIG. 11.

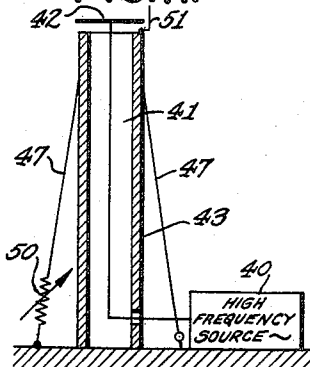


FIG. 14.

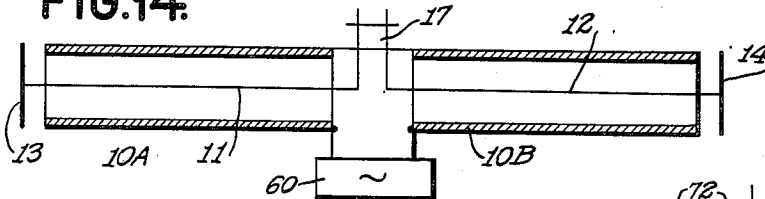
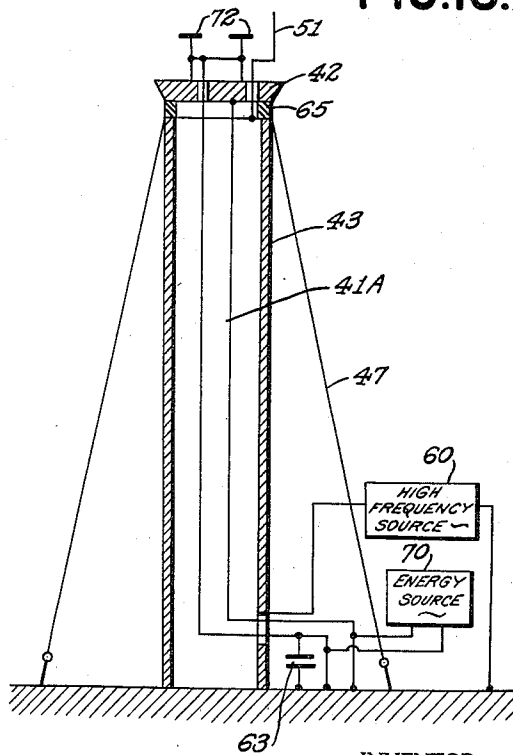
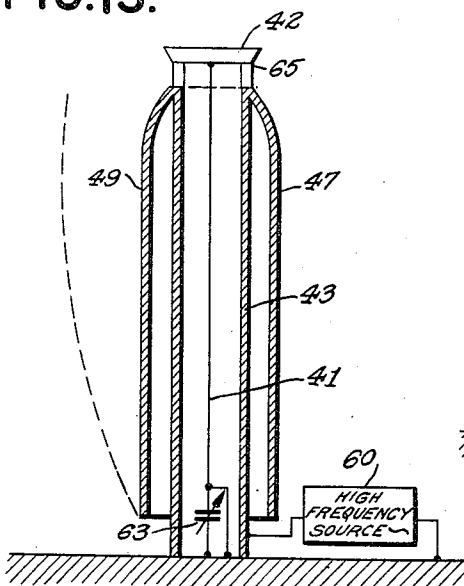


FIG. 16.

FIG. 15.



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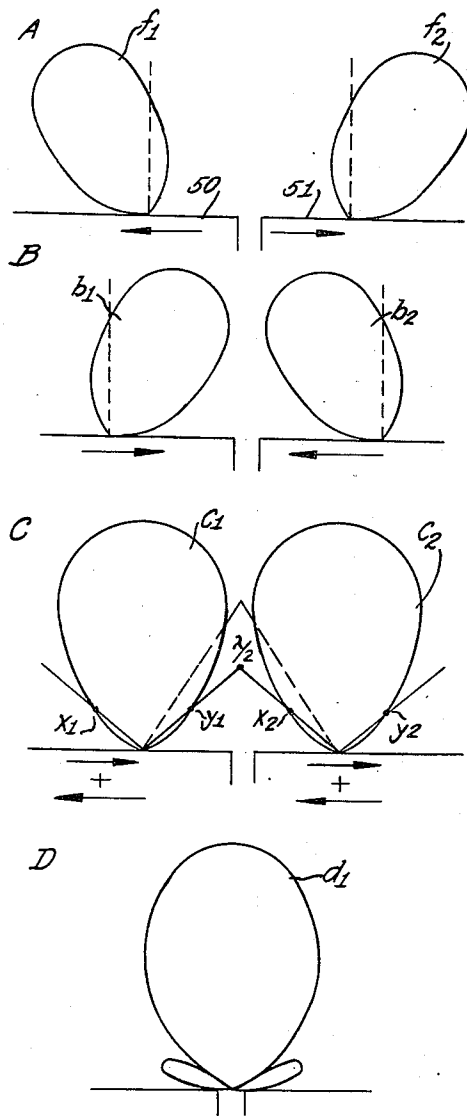
TRANSMITTING ANTENNA

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4 Sheets-Sheet 4

FIG.12.

EXTREMELY FINE RADIATOR



LARGE DIAMETER RADIATOR

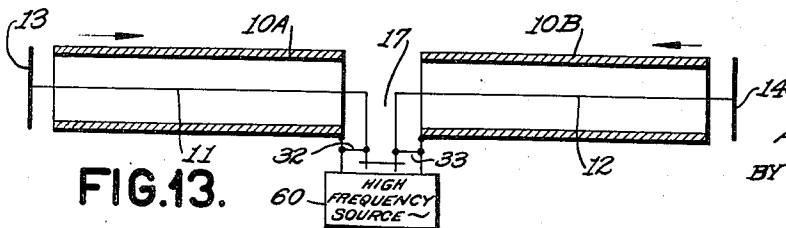
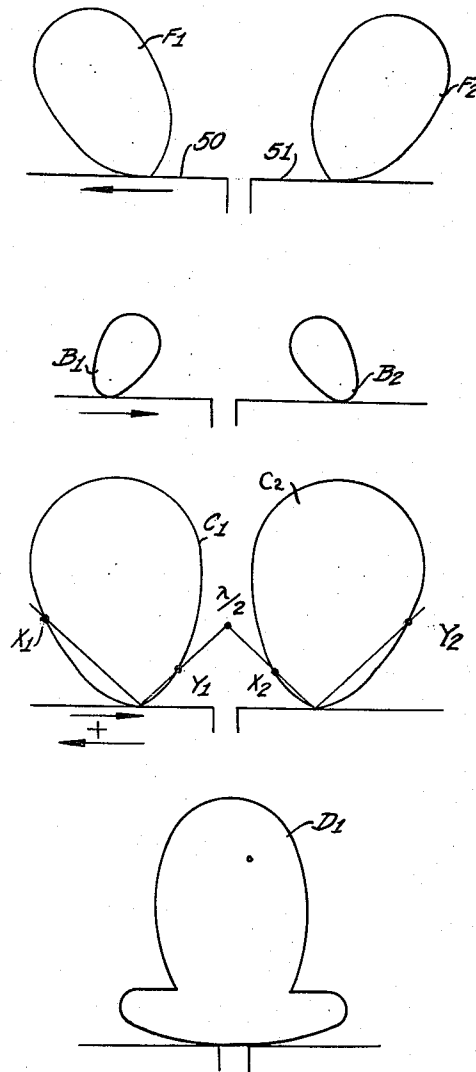


FIG.13.

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UNITED STATES PATENT OFFICE

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TRANSMITTING ANTENNA

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Application April 9, 1941, Serial No. 387,653

12 Claims. (Cl. 250—33)

This invention relates to antennae and more particularly to antenna systems generally useful for transmitting signals.

In transmitting antenna systems heretofore proposed it has generally been found necessary to take special precautions or to resort to special constructions of harmful effects on the transmission characteristics if accumulations such as sleet are to be avoided.

Moreover, in order to secure the desired distribution, particularly in broadcast antennae it has been considered necessary to have the antenna greater than a half wavelength long, or to insulate the antenna from ground and provide special loading at the upper end, usually in the form of a capacity area and a large choke coil. These are generally undesirable features since they entail additional expense in the mast and/or the insulating means therefor.

It is an object of my invention to provide antenna structures which avoid the above outlined difficulties and in addition furnish further advantages.

One feature of my invention comprises an antenna structure of the dipole or mast form, in which energy is supplied to one end of a central conductor, the other end of which is operatively coupled with an outer conductor or conductor system. By this arrangement the desired current distribution in the radiating portion of the antenna may be more readily achieved. Furthermore, the outer conductor need not be insulated from the earth, and no insulators capable of withstanding high potentials are required.

According to a further feature of my invention, a mast or tower antenna may be provided, in which energy is fed to the radiator by means of a conductor located within the metal tower structure. This conductor is terminated at one end in a capacity area, or is coupled to the tower by means of a loop. Additional conductor elements, or a conductor element, are connected at their upper end to the mast either at its top or at some intermediate point, and are held in place at their lower ends in insulated spaced relation with respect to the mast, by simple insulators or by impedance elements or by their own inherent rigidity.

A still further feature of my invention resides in a feeding system for antennae of the type discussed generally above by which a desired distribution of energy, without accentuated trouble from minor lobes may be obtained.

While I have outlined a few of the features

above, a better understanding of my invention and the features and objects thereof may be had from the particular description thereof made with reference to the accompanying drawings in which

Figs. 1-4 show embodiments of dipole antennae according to my invention;

Figs. 5 and 6 show structural arrangements of dipole antennae supports according to my invention.

Figs. 7-11 show various vertical mast antennae according to my invention.

Fig. 12 is a diagram used in explaining a further feature of my invention;

Figs. 13 and 14 are dipole antennae incorporating a further feature of my invention, and

Figs. 15 and 16 are mast or tower antennae structures incorporating the further features of my invention.

Turning to Fig. 1, a dipole unit is shown comprising an outer conductor 10 which may be of a single tubular form, inner conductors 11, 12 extending from a point near the center of conductor 10 to points just outside the outer ends of the conductor 10 and capacity areas 13, 14, connected to the outer ends of conductors 11, 12, respectively. Energy is supplied to the antenna over a transmission line 15 from a high frequency source 16. In order to control the energy fed to the antenna a transmission line section 17 provided with a short circuiting bar 18 is connected to conductors 11 and 12, and transmission line 15 is coupled at a point intermediate the short circuiting bars and the conductors. It is clear, however, that if the proper tuning and energy transfer is already furnished by the antenna system, this coupling arrangement may be omitted.

It is found that when conductor 10 is made substantially equal to one-half of a wavelength long, a voltage distribution as shown in dotted lines by the curve 19 is obtained. This may be explained in the following manner: Energy fed to unit conductors 11, 12 is of opposite phase so that by reason of the capacity areas 13, 14, traveling waves of opposite polarity are induced in the outer conductor and travel in opposite directions, as indicated by the arrows 20, 21. At the center point of the antenna these units meet and since they are of substantially equal magnitude and opposite phase they cancel one another so that at the mid-point of the conductor the current is zero. This condition obtains so long as the two arms 11 and 12 are at substantially the mid-point of conductor 10,

regardless of the length of conductor 10. If conductor 10 is made greater than a half wavelength long then a distribution of the type shown by the solid curve 22 is obtained. This curve presents a current loop at the center of the antenna and current nodes at points a quarter of a wavelength away from this center point. It may be seen then that this arrangement while achieving the desired distribution will have considerable voltage at the terminal ends thereof. As a consequence a relatively large insulator would be necessary to assure the proper insulation of plates 13, 14 of conductor 10.

In the arrangement shown in Fig. 2 the construction is very similar to that shown in Fig. 1, except that instead of a single continuous conductor 10, two half conductors 10A, 10B are provided insulated from one another at the central point by an insulating ring 23. Because of this arrangement wherein the parts 10A and 10B are insulated one from another, there will not be complete cancellation at this point, but instead a current node will exist at this point, as indicated by the curves 22A and 22B. Accordingly, this arrangement does not necessitate the provision of large insulators for supporting plates 13 and 14 at the end. However, this arrangement requires an insulating arrangement at the middle which must, therefore, contain considerable voltage.

In accordance with the arrangement shown in Fig. 3, the advantage of the distribution of Fig. 2 together with the preferred mechanical construction of Fig. 1 may be achieved. According to this arrangement the antenna structure itself resembles that of Fig. 1 with the addition that to each of the outer ends of central conductor 10 is connected a further outer sheath 24, 25, these outer conductor arrangements being spaced one from another. The central conductor 10 may be used to support these sheaths and it is not then necessary to provide insulators in the mechanical structure itself. The outer conductive means 24, 25 need not be solid tubular members but may be, if desired, merely a few wire strands arranged around the periphery of the central conductor 10 and connected at one end to the end of this conductor. By this arrangement the necessity of providing large strain insulators or large insulators for withstanding high voltage drop is avoided.

If desired, the outer conductors may be made of any desired length and need not extend to a point near the center of the conductor 10, as shown in Fig. 3. For example, conductive arrangement 24, 25 may be arranged to extend only a fraction of the length of the tube 10, as shown in Fig. 4. This arrangement provides a distribution substantially as indicated at 22A, 22B in this figure.

Dipole units of the type shown in Figs. 1, 3 and 4, lend themselves readily to simple mast construction arrangements such as shown in Fig. 5. In this arrangement the outer conductive means is made in two parts 10C, 10D which are connected at their inner end to a metal supporting mast 30. Energy from the signal source 16 may be supplied over a pair of conductors 15 which may be connected directly at their upper end to a metal plate terminating mast 30. A short circuiting bar 31 may be properly adjusted so that the transmission line 15 is terminated at this point. The central conductors 11, 12, may be energized in the desired degree by means of short connecting lines 32, 33, connecting the trans-

mission line section 17 at the desired point to line 15. Instead of capacitive coupling means at the ends of conductors 11, 12, the arrangement of Fig. 5 provides coils 13A, 14A, connected at one end to conductors 11, 12, respectively, and at the other end to conductors 10C, 10D. It is thus shown that a dipole arrangement in which practically no insulating structures are required, is thus provided. In order to protect the arrangement from the elements, insulating covers 34, 35, may be provided over the coupling coils 13A, 14A and the open ends of conductors 10C, 10D. Any number of units of this type may be provided on the mast to secure the desired array effect.

It has been found that an antenna unit of this general construction as shown in Fig. 5 is not appreciably affected by reason of ice accumulation on the dipole element. In a dipole unit of this type which was constructed and tested, it was found that even encasing the whole outer conductor in a block of ice extending four inches out from the conductor arrangement made no appreciable effect in the transmission characteristics of the antenna.

In Fig. 6 is shown an array system of antenna units similarly constructed to those shown in Fig. 5. However, in this figure the dipoles are arranged with capacitive coupling means 13, 14, at their ends instead of the coils shown in Fig. 5. It can be clearly seen that with this arrangement the energy may be readily adjusted in different units of the array if desired merely by changing the coupling point of the short coupling lines 32, 33 with respect to sections 17. From the above description it is clear that the dipole transmitting unit as set forth above, possesses very desirable characteristics. No necessity for providing insulation is present in this case. It should be further understood that if a different type of distribution is desired, outer conductor sections, such as 24, 25 of Figs. 3 and 4, may be provided on the dipole unit of Figs. 5 and 6. Furthermore, it should be understood that these outer conductor elements such as 24, 25, may if desired, be connected to a point intermediate the length of the conductor 10, it being merely necessary in order to secure the desired distribution that the open ends of these conductor arrangements be faced toward the center of the unit.

The structural arrangements described in connection with the dipole system shown in Figs. 1 to 6, lend themselves readily to application of mast type antennae. This type antennae may be considered as merely a half of one of the dipole units the other portion thereof being the reflected image in the earth. In Fig. 7 is shown one type of mast arrangement in which the high frequency source 40 is connected over a transmission line 41 to a capacity area 42. This conductor 41 is arranged internally of a mast 43, which is mounted directly on the ground and arranged to make further electrical connection therewith. Conductor 41 extends from a point near the bottom of mast 43 to a point just above the mast. The distribution from this arrangement is indicated by the curve 44. It is seen that this curve has the lobe at the ground and for this reason is not generally desirable for broadcast purposes.

A more suitable distribution may be achieved by means of the arrangement shown in Fig. 8 wherein mast 43 is supported from the earth by means of insulators 45. This arrangement, how-

ever, has the disadvantage that the heavy mast 43 must be supported on grid screen insulators. Such a construction is relatively expensive and it is desirable to avoid this if possible.

A preferred mast antenna arrangement is shown in Fig. 9 wherein an outer conductor arrangement 47, which may be merely a number of conductors arranged around mast 43 is provided, these conductors 47 being connected to the mast and extending toward the earth in spaced relation from the mast. With this arrangement simple strain insulators 48 may be provided and these need not be designed to support the entire weight of the mast as is required in accordance with the structure of Fig. 8.

Fig. 10 is similar to Fig. 9 except that the outer conductor arrangements 47 extend only a short distance toward the earth. This gives a higher point of radiation for the system than the arrangement of Fig. 9 and may be desirable in some cases.

In Fig. 11 an arrangement somewhat similar to Figs. 9 and 10 is shown. However, in this arrangement the outer conductors 47 are arranged at a point below the top of mast 43 and may, if desired, be connected to a suitable impedance device such as shown at 50, to the earth. In addition a lightning protector 51 is shown extending above plate 42 and connected directly to the grounded mast 43. This conductor 51 extends through an opening in capacity area 42 and serves to protect the entire system from lightning.

It should be realized that the various features shown in Figs. 7 and 8 may be interchangeably used as desired, these specific examples being shown only by way of illustration. Many variations in the exact structure may be made within the scope of this invention.

As shown in the discussion above in connection with Figs. 1 to 11, the antenna arrangement according to my invention has certain very marked advantages. I have, however, found that still further improvements of operation may be made in accordance with a system of this type. It is found that when a large diameter radiator is used the distribution of the radiation pattern is not all that may be desired. The reason for this variation in the radiation pattern will be more fully explained with reference to Fig. 12 showing various radiation diagrams. The radiation diagram from a large diameter radiator is found to depart greatly from the theoretical value that it should have considering the length of the unit. Accordingly, while this large diameter radiator has the advantage of greater radiation resistance and less losses, it does not present sharp minimum and nulls as in the case of the fine radiator arrangements.

In considering this phenomenon a dipole radiator consisting of two arms 50 and 51 will be considered, this arm radiator being such that each of the arms 50 and 51 is slightly greater than one half of a wavelength. The energy producing the pattern in each half of the dipole may be considered as that produced by two traveling waves, one traveling outward and the other one reflected from the ends and traveling back toward the center of the dipole. In an article entitled "A Discussion of Methods Employed in Calculations of the Electromagnetic Field of Radiating Conductors" by the present inventor, published in Electrical Communication for July 1936, No. 1, vol. 15, the method of calculating the electromagnetic field from a radiating conductor

taking into consideration traveling waves, has been thoroughly set forth.

Considering conductors 50, 51 it is clear, as shown in the upper diagram of Fig. 12, that the radiation pattern f_1, f_2 from the extremely fine radiator having theoretically a substantially zero diameter, and the radiation diagram $F1, F2$ from the large diameter radiator caused by the forward wave fed to the units 50, 51, are identical. However, the radiation patterns b_1, b_2 , caused by the back waves in the fine radiators are substantially mirror reflections of f_1, f_2 , while the radiation pattern produced by the back waves in the larger conductors are on a much smaller scale, as shown at $B1, B2$. This reduction in the size of the radiation pattern for the larger diameter radiators is due to the decreased radiation resistance, since with the large diameter conductor a considerable amount of the energy is lost by radiation so that the back wave is much lower in amplitude than the forward wave. Thus the arrows shown in connection with the arrangement of Fig. 12 may indicate the relative signal strength.

Accordingly, when the front and back radiation patterns are combined, as shown at C, Fig. 12, those from the fine radiator will be symmetrical, as shown at c_1, c_2 , whereas the combined patterns for the large diameter radiator will be inclined one to another, as shown at $C1, C2$. These two patterns $C1, C2$, add together to produce the overall radiation pattern of the dipole, as shown at d_1 . As a consequence the length of x_1, y_1, x_2, y_2 , are equal and the radiation d_1 , therefore, produces a cancellation at this point, so that one large lobe and two small lobes are provided with a complete null at a point between these lobes. However, in the case of the large diameter conductor, points $X1, Y1$, and $X2, Y2$, are not equal in length and consequently complete cancellation does not take place at this angle. The total pattern $D1$, therefore, has a radiation pattern which is somewhat lower in the principal direction than for the fine radiator and does not have any null. Furthermore, because $X1, Y1$ are predominantly large, the minor lobes of this pattern are considerably larger than in the case of the fine conductor arrangements.

It can be seen that because of this phenomenon it was previously found to be not possible to secure the desired radiation distribution for mast antenna for example, which were greater than a half wavelength long. In this arrangement when the relatively large masts were used, it was found that the sky-wave was greatly exaggerated and it was not possible or practical to eliminate this sky-wave or to reduce its magnitude to the desired extent.

In accordance with my invention I provide an arrangement whereby the harmful effect of the large diameter radiator may be modified or completely overcome. An explanation of the circuit arrangement for securing this adjustment will be made in connection with Fig. 13. In this figure a high frequency source 60 is provided, and an antenna consisting of central conductors 11, 12, having coupling arrangements 13, 14, whereby the inner conductor is coupled to an outer conductor such as 10A, 10B is shown. It is clear from the explanation previously given, that energy supplied to conductors 11, 12, will cause a wave to travel along outer conductors 10A, 10B, toward the center of the dipole arrangement. If, then, energy is supplied from source 60 directly to the outer conductors, the energy supplied from

the inner conductors over the coupling capacities may be adjustably controlled so as to produce a compensation for the loss of energy in the back waves. By this arrangement the adjustment of the radiation pattern to any desired form may be accomplished. Upon investigating this property it was found that an arrangement such as shown in Fig. 14, produced essentially complete compensation for the attenuation of the wave in the outer conductor of the system. In this arrangement the system shown is substantially the same as that shown in Fig. 13. However, in this case no connection whatsoever is made to the section 17 connected to conductors 11 and 12 of the arrangement. It appears, accordingly, that substantially complete compensation may be achieved merely by arranging the central conductors together with a suitable tuning arrangement such as represented by 17 in a mast antenna structure of this type, or in a dipole arrangement as shown in Fig. 14. It is also clear that with this arrangement the outer conductor system described in connection with the previous figures may be also used so as to secure the reversal of the current in the radiating conductor, if this is also desired.

The arrangement of Fig. 14 lends itself readily to mast antenna construction. In Fig. 15 is shown a mast antenna comprising a central mast portion 43 provided with an outer conductor arrangement 47. Within mast 43 is arranged the central conductor 41 connected to the high frequency source 60. Mast 43 is mounted directly on the earth and is electrically connected thereto. An impedance adjusting arrangement exemplified by condenser 63 is provided connecting the lower ends of conductor 41 to ground. The capacity area 42 connected at the upper end of central conductor 41 is separated from mast 43 by suitable small insulators 65. With this arrangement suitable adjustment of condenser 63 may be made so that the desired horizontal distribution of energy may be readily achieved.

In Fig. 16 a still further embodiment of a mast antenna arrangement using this principle, is disclosed. This system differs from that of Fig. 15 primarily in that a central conductor instead of being a single conductor is made as a two conductor transmission line 41. This transmission line may then be connected directly to earth at its lower end and a condenser may be provided at some point to secure the desired adjustment as indicated at 63. The radiation of energy from source 60 by means of the mast may take place in the same manner as previously outlined. Since the central conductor line 41A is not electrically connected to receive energy directly from source 60, it is immaterial how many conductor arrangements are brought down. This transmission line 41A may accordingly, then be used as a transmission line for supplying energy from a further source 70 which may, if desired, be of higher frequency than source 60. By suitable choice of the connection point of source 70 to line 41A with respect to the short circuited end at the ground, the proper impedance relation for feeding energy along line 41A may be provided. A short wave radiator 72 may then be provided mounted on top of condenser area 42. In addition a lightning protection rod 51 is arranged connected to the top of mast 43 and extending above radiators 72.

It is clear that the outer conductor element 47 may be omitted if desired and the antenna tower may be operated in an arrangement simi-

lar to Fig. 7. Similarly, if desired, any of the forms shown in Figs. 7 to 11 may be utilized in place of the particular arrangement shown in Fig. 16.

While I have described a new specific example of my invention, it should be distinctly understood that these are submitted merely as illustrations of the invention and not as limitations on the scope thereof. Any modifications and changes may be made within the teachings of my invention, it being only necessary to embody therein the principles of the invention as described above. While tower structures are practical from a mechanical standpoint, it is also clear that the principles of my invention apply to antenna arrangements which are supported on independent supporting structures as well.

What I claim is:

1. A radio antenna comprising a hollow conductor means extending from a position adjacent to a feeding point to a more distant point, an inner conductor means arranged within the hollow of said hollow conductor means, extending throughout the length and slightly beyond the distant end thereof, means for coupling the distant ends of said hollow conductor means and said inner conductor means with one another, and means for supplying energy to at least one of said conductor means at said feeding point.

2. A radio antenna according to claim 1, wherein said antenna comprises two hollow conductor means and two inner conductor means, extending in opposite directions.

3. A radio antenna according to claim 1, wherein said hollow conductor means consists of a plurality of wires arranged to define a hollow periphery.

4. A radio antenna system according to claim 1, wherein said hollow conductor means is greater than one quarter wavelength at the operating frequency long.

5. A radio antenna according to claim 1, wherein said hollow conductor means is between a quarter wavelength and a half wavelength long.

6. A radio antenna according to claim 1, wherein said hollow conductor comprises a radiating mast structure mounted directly on the earth to produce a direct ground, and outer conductive means galvanically connected to the upper end of said mast structure and extending downwardly therefrom in spaced relation from said mast and said earth, and said means for coupling comprises a capacity area mounted on insulators on the top of said mast structure.

7. A radio antenna according to claim 1, wherein said hollow conductor means comprises a central hollow conductor member and an outer conductive means galvanically coupled to the outer end of said hollow conductive means and extending back toward said feeding point in spaced relation with respect to said hollow conductive means.

8. A radio antenna according to claim 1, wherein said hollow conductor comprises a radiating mast structure mounted directly on the earth to produce a direct ground, and outer conductive means galvanically connected to the upper end of said mast structure and extending downwardly therefrom in spaced relation from said mast and said earth, and said inner conductor means comprises a transmission line, further comprising means for supplying high frequency energy to outer conductor at a point near said ground, and phase adjusting means inter-

connecting said inner conductor means and ground.

9. A radio antenna according to claim 1, wherein said hollow conductor comprises a radiating mast structure mounted directly on the earth to produce a direct ground, and outer conductive means galvanically connected to the upper end of said mast structure and extending downwardly therefrom in spaced relation from said mast and said earth, and said inner conductor means comprises a transmission line, further comprising means for supplying high frequency energy to outer conductor at a point near said ground, other radiating means mounted on said capacity area, means for coupling the transmission line forming said inner conductor to said other radiating means, and a separate source of energy coupled to the end of said transmission line near said ground for supplying energy to said other radiating means.

10. A radio antenna according to claim 1, further comprising an energy source for supplying energy to said outer conductor means at said feeding point, and connections to said source for

supplying energy from said source of the desired amplitude and phase to said central conductor means.

11. A radio antenna comprising a hollow conductive element of relatively large diameter, means for supplying energy to one end of said hollow conductive element, and means for reducing the effects of attenuation of energy in said hollow conductor comprising an inner conductive means arranged within said hollow conductive element extending substantially throughout the length thereof and slightly beyond the end of said hollow conductive element remote from the end at which energy is supplied, coupling means for coupling the extended end of said conductor and said remote end of said hollow conductive element and means for adjusting the tuning of said conductor.

12. A radio antenna system according to claim 11, further comprising means for supplying a controllable amount of energy to said conductor at the end opposite to said coupled end.

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